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THE ANNUAL VARIATION OF TOTAL OZONE IN THE SOUTHERN HEMISPHERE [1]

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ABSTRACT

A summary of Southern Hemisphere total ozone measurements made during the quiet sun period of 1960–1965 showed no pronounced changes from the annual variation pattern observed during the preceding active-sun years. Nor was any difference found during 1960–1965 between the annual variation of total ozone in the South Pacific area and the annual trend at other longitudes in the Southern Hemisphere. The present analysis does reemphasize that dissimilarities in the development pattern of the springtime ozone maxima in the Southern and Northern Hemispheres require that the ozone general circulation models be different in the two hemispheres.

Following the International Geophysical Year (1957–1958), several hemispheric and worldwide summaries of the annual and latitudinal variation of total ozone were published. Godson (1960), London (1962), and MacDonald (1963) constructed mean distribution diagrams for the Northern Hemisphere while a month-by-month variation for both hemispheres during the IGY was given by Ramanathan (1961). Kulkarni (1962) studied the distribution of total ozone in the Southern Hemisphere from IGY and pre-IGY observations and compared its pattern to that in the Northern Hemisphere. Dobson (1966) has pointed out the contrasts in the annual variations of ozone between the Arctic and Antarctic Regions as revealed by the intensive observations during the International Quiet Sun Years (1964–1965).

The present study is an analysis of the Southern Hemisphere total ozone observations for the period 1960–1965 that includes the International Quiet Sun Years. These data are published in six volumes of *Ozone Data for the World 1960–1965* (Meteorological Branch, Department of Transport 1961–1966). A compilation of the monthly means of total ozone at 22 Southern Hemisphere stations comprises the information used for the present analysis. A listing of these stations and their period of record is given in table 1. The 5 yr of observations at the Amundsen-Scott station are unprecedented and allow a hemispheric ozone analysis to be extended to the Pole without extrapolation.

The monthly mean values (Meteorological Branch, Department of Transport 1961–1965) were used without alteration. No attempt was made to filter out biennial or other long-term periodicities since the length of record at some stations was only a single year. When monthly means from more than 1 yr were available for a station, these means were averaged together to give a single value for each month. In the final analysis of the data, less weight was given to monthly averages compiled from fewer than five observations per month. These less reliable data occurred between April and August at the stations south of 65° S. and were due to the lack of sunlight during the polar night. During the remainder of the year, most of the averages in these higher latitudes were derived from a full schedule of measurements. However, even in this period, the monthly ozone averages in the zone between 65° S. and 75° S. showed less consistency between stations and also between years at one station than did the monthly averages in other latitudinal zones.

The annual variation of ozone between 0° and 90° S. is shown in figure 1. The isopleths give total ozone in units of 10^{-3} cm (S.T.P.). The monthly averages in this figure are similar to the IGY Southern Hemisphere values compiled by Ramanathan and by Kulkarni. No significant change in total ozone magnitude is apparent in the Southern Hemisphere between the periods of active and quiet sun.

The principal features of the annual distribution of ozone in these latitudes are the primary maximum in September–October at 50° S., the secondary maximum in November–December at 80°–85° S., and the minimum values in the polar latitudes during the winter months. The pattern of an ozone maximum that covers a large middle-latitude zone in the spring and then in winter extends poleward toward another smaller separate area of

TABLE 1.—*Southern Hemisphere total ozone stations having a record of two or more months of regularly scheduled observations during the period 1960–1965*

Station	Latitude (S.)	Longitude	Years of observation
Gan, Maldive Islands	0° 41′	73° 09′ E.	1964–65
Canton Island, South Pacific	2° 46′	171° 43′ W.	1965
Huancayo, Peru	12° 02′	75° 13′ W.	1964–65
Pretoria, South Africa	25° 45′	28° 14′ E.	1964–65
Brisbane, Australia	27° 28′	153° 02′ E.	1960–65
Woomera, Australia	31° 09′	136° 48′ E.	1961
Buenos Aires, Argentina	34° 35′	58° 29′ W.	1965
Salisbury, Australia	34° 43′	138° 39′ E.	1961
Aspendale, Australia	38° 02′	145° 06′ E.	1960–65
Wellington, New Zealand	41° 17′	174° 46′ E.	1960, 1965
Puerto Montt, Chile	41° 27′	75° 50′ W.	1964–65
Kerguelen Island, South Indian Ocean	42° 20′	70° 15′ E.	1960–64
Stanley, Falkland Islands	51° 42′	57° 52′ W.	1963
Macquarie Island, Australia	54° 30′	158° 57′ W.	1963–65
Argentine Island, Antarctica	65° 15′	64° 16′ W.	1960–65
Mirny, Antarctica	66° 33′	93° 01′ E.	1960–62, 1964–65
Dumont d'Urville, Antarctica	66° 44′	140° 01′ E.	1960–62
Base King Badouin, Antarctica	70° 26′	24° 19′ E.	1965
Hallett, Antarctica	72° 19′	170° 13′ E.	1961–63
Halley Bay, Antarctica	75° 31′	26° 44′ W.	1960–65
Byrd, Antarctica	80° 01′	119° 31′ W.	1962–65
Amundsen-Scott, Antarctica	90° 00′		1961–65

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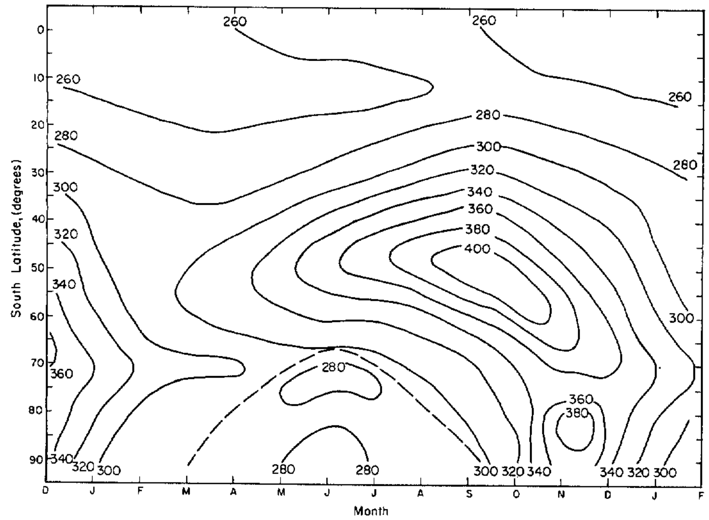

FIGURE 1.—Mean distribution of total ozone in the Southern Hemisphere (1960–1963). Units are 10^{-3} cm (STP). The heavy dashed line encloses the area of winter darkness.

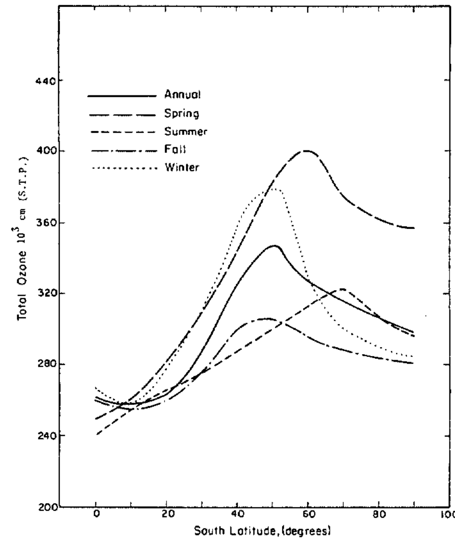

FIGURE 2.—Variation of total ozone with latitude and season in the Southern Hemisphere.

maximum ozone is typical of individual years as well as in the average shown here. This pattern was present in Ramanathan's analyses for 1957–1959 and appeared in each of the plots made by the author for the years 1960–1965.

Before computing the monthly averages over the entire hemisphere for this study, the stations were divided into those in or bordering on the Pacific Ocean and those located in other portions of the hemisphere. The dividing longitudes were 140° E. and 60° W., and Byrd (80° S.) and Amundsen-Scott (90° S.) stations were not considered. A comparison of these Pacific and non-Pacific data showed that both regions had annual patterns similar to figure 1 with only slight variations. An annual maximum of over 400 10^{-3} cm (STP) in the Pacific occurred at 55° S. in October; while outside the Pacific area, the maximum did not reach 400 10^{-3} cm (STP) and occurred near 50° S. in August. The combination of these two sets of data results in the hemispheric maximum isopleth of 400 10^{-3} cm (STP) being elongated over 3 mo and 15° of latitude.

By following the example of London, another depiction of the Southern Hemisphere ozone distribution is shown in figure 2. The seasonal curves of ozone versus latitude are the midseasonal values taken from figure 1; the annual curve was compiled directly from the annual averages of total ozone for those stations having at least 12 consecutive months of observations during 1960–1965. The features that distinguish this diagram from London's Northern Hemisphere counterpart are the peaking of the winter, spring, and annual curves in the 50°–60° S. latitude zone and the sharp gradient poleward of this zone. In the Northern Hemisphere, the gradient in these latitudes is small and is directed equatorward for the spring and annual curves.

The development of the middle-latitude ozone maximum earlier than the polar maximum is markedly evident in figure 1. A similar but less-pronounced sequence was indicated for the Northern Hemisphere in the analyses by London, MacDonald, and Ramanathan but was not shown by Godson. The Southern Hemisphere pattern of two ozone maxima with the larger one occurring in the middle latitudes is not duplicated in the Northern Hemisphere where there is a single springtime maximum at 80° N. As a consequence of these hemispheric differences in the seasonal variation of ozone, no model of ozone general circulation developed for one hemisphere can be used for the other hemisphere without alteration of the magnitude or location of the forces driving the circulation so that contrasts can be explained.

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REFERENCES

Dobson, Gordon M. B., "Annual Variation of Ozone in Antarctica," *Quarterly Journal of the Royal Meteorological Society*, Vol. 92, No. 394, Oct. **1966**, pp. 549–552.

Godson, Warren L., "Total Ozone and the Middle Stratosphere Over Arctic and Sub-Arctic Areas in Winter and Spring," *Quarterly Journal of the Royal Meteorological Society*, Vol. 86, No. 369, July **1960**, pp. 301–317.

Kulkarni, R. N., "Comparison of Ozone Variations and of Its Distribution With Height Over Middle Latitudes of the Two Hemispheres," *Quarterly Journal of the Royal Meteorological Society*, Vol. 88, No. 378, Oct. **1962**, pp. 522–534.

London, J., "The Distribution of Total Ozone Over the Northern Hemisphere," *Sun at Work*, Vol. 7, No. 2, 2d quarter, **1962**, pp. 11–12.

MacDonald, V., "An Atlas of Total Ozone Distribution October 1958–September 1959," Publication No. 61, Arctic Meteorology Research Group, Department of Meteorology, McGill University, Montreal, Canada, **1963**, 91 pp.

Meteorological Branch, Department of Transport, *Ozone Data for the World 1960–1965*, Vols. 1–6, Toronto, Ontario, Canada, **1961–1966**.

Ramanathan, K. R., "Atmospheric Ozone and Some Problems of the Stratosphere," *Proceedings of the International Union of Geodesy and Geophysics Symposium on Atmospheric Ozone–II, Arosa, Switzerland, August 1961, Geophysics Monograph* No. 19, Institut geographique National, Paris, **1961**, pp. 1–9.

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